Orion Interior Acoustic Environment Modeling with a Mock-up

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Acoustic modeling can be used to identify key noise sources, determine/analyze suballocated requirements, keep track of the accumulation of minor noise sources, and predict vehicle noise levels at various stages in vehicle development, first with estimates of noise source levels, and later with experimental data.

The Johnson Space Center (JSC) Acoustics Office constructed an Orion crew module acoustic mock-up (figure 1) and associated acoustic model (figure 2) with incrementally increased fidelity, and validated the accuracy of the model in predicting the mock-up interior sound pressure level under various noise sources and vehicle configurations. Confidence in modeling techniques has been gained through extensive model validation.

The initial configuration of the crew module acoustic mock-up contained only a 12-faced enclosure of two-layered medium-density fiberboard wall. This dense wall material was used for trapping sound inside the mock-up to simulate on-orbit operation. The volume of the mock-up interior matches the Orion pressure vessel, with the surface area of the mock-up also very close to that of the vessel's.

A reverberation time T60 measurement using a dodecahedron speaker was performed to characterize the acoustic absorption of the mock-up interior. A model of this bare mock-up was constructed. The predictions of the model under the excitation of single and two reference sound sources were compared to sound pressure level measurements inside the mock-up. Excellent agreement was found. Furthermore, patches of sound absorptive Thinsulate™ material were attached to interior surface of the mock-up. The model was used to predict the area of these patches for reaching targeted absorption level, and was verified by T60 measurement. Scientists performed Modified Rhyme Tests with various simulated noise environments inside the mock-up to develop a new requirement for Orion post-landing speech interference limit.

As an alternative method of modeling the absorption of the mock-up interior, scientists performed impedance tube testing of sound absorptive materials. They identified several acoustic material properties by curve fitting the measured absorption. The identified properties were then used to construct a single- or multi-layered noise control treatment lay-up model. The lay-up models were placed inside the mock-up system model to account for the absorption contribution of noise control treatments.
The JSC Acoustics Office uses an impedance tube for acoustic absorption and transmission loss measurements. The tube can be configured with two or four microphones, and is used for absorption or transmission loss measurements, respectively.

Fig. 1. *Orion crew module acoustic mock-up exterior, wall made of two medium-density fiberboard sheets, 1 in. total thickness.*

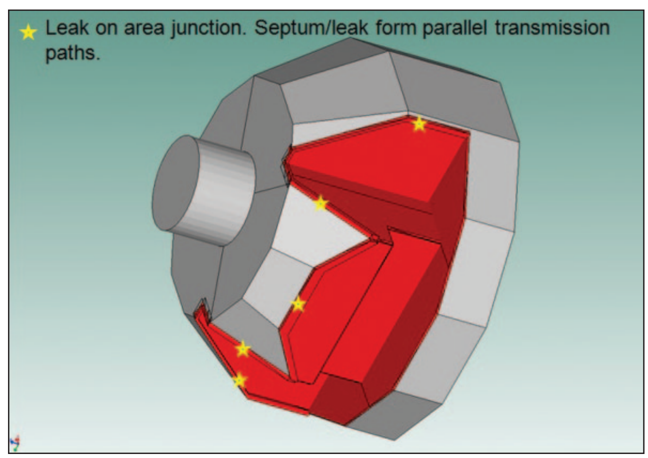

Fig. 2. *Orion crew module acoustic mock-up model with leaky gap sealing.*

Fig. 3. *Reverberation time measurement of Orion crew module acoustic mock-up with bare Environmental Control and Life Support System wall and open gap.*

The fidelity of the bare mock-up and corresponding model were then increased by including simple ventilation systems. The airborne sound powers of ventilation fans were measured by sound intensity mapping, since the sound power levels were not known beforehand. This was opposed to earlier studies where reference sound sources with known sound power levels were used. Comparisons of model predictions with measurements in the mock-up showed good agreement.

The fidelity of the mock-up and the model were further increased by including an Environmental Control and Life Support System (ECLSS) wall, and associated closeout panels with a gap between the ECLSS wall and the mock-up wall. The effect of sealing the gap and adding sound absorptive treatment to the ECLSS wall were also modeled

Fig. 4. *Orion crew module acoustic mock-up with sealed gap and Thinsulate™ covering the cabin side of the Environmental Control and Life Support System wall.*

and validated under the following configurations: bare mock-up and bare ECLSS wall with open gap; bare mock-up and bare ECLSS wall with sealed gap; bare mock-up and ECLSS wall with sealed gap and one layer of Thinsulate™ completely covering the cabin side of the ECLSS wall; and bare mock-up and ECLSS wall with sealed gap, and one layer of Thinsulate™ covering part of the ECLSS wall on the cabin side and the remaining ECLSS wall on the ECLSS bay side (figures 3 and 4). Both measured and predicted sound pressure levels show that deploying part of available Thinsulate™ treatments inside the ECLSS bay is more effective in the sound pressure level in the cabin than deploying all the treatment in the cabin.

Aluminum sheets/tapes were attached to the interior surfaces of the mock-up wall recently for increasing the interior reverberation time to a more realistic level because the medium-density fiberboard wall is more absorptive compared to a typical metallic surface of a spacecraft. Validation of the bare mock-up model showed excellent agreement between model predictions and measurements. The mock-up model with ECLSS wall, Thinsulate™ treatments, and open/sealed gaps will be validated soon.

The fidelity of the mock-up will be further increased in the near future by including a secondary structure, storage lockers, and snorkel fan.